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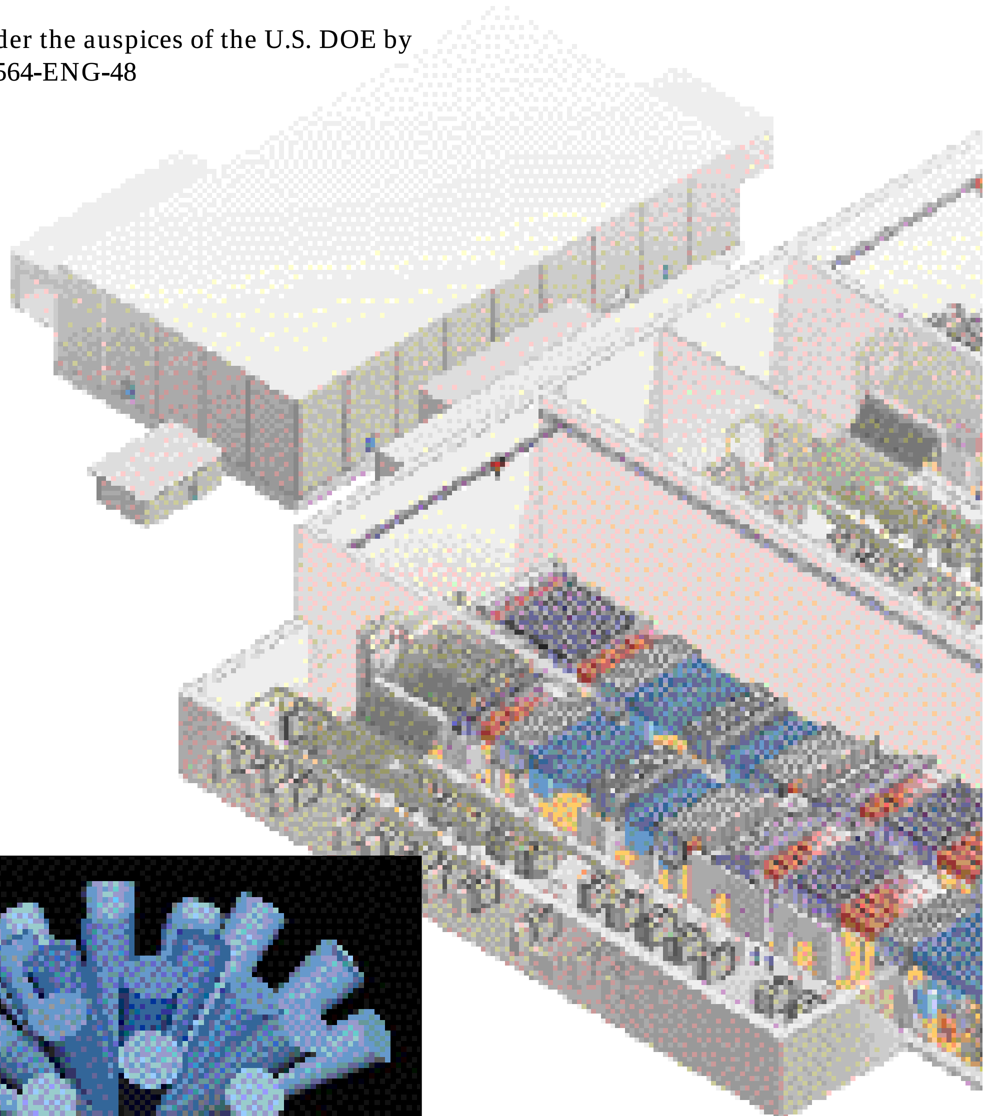
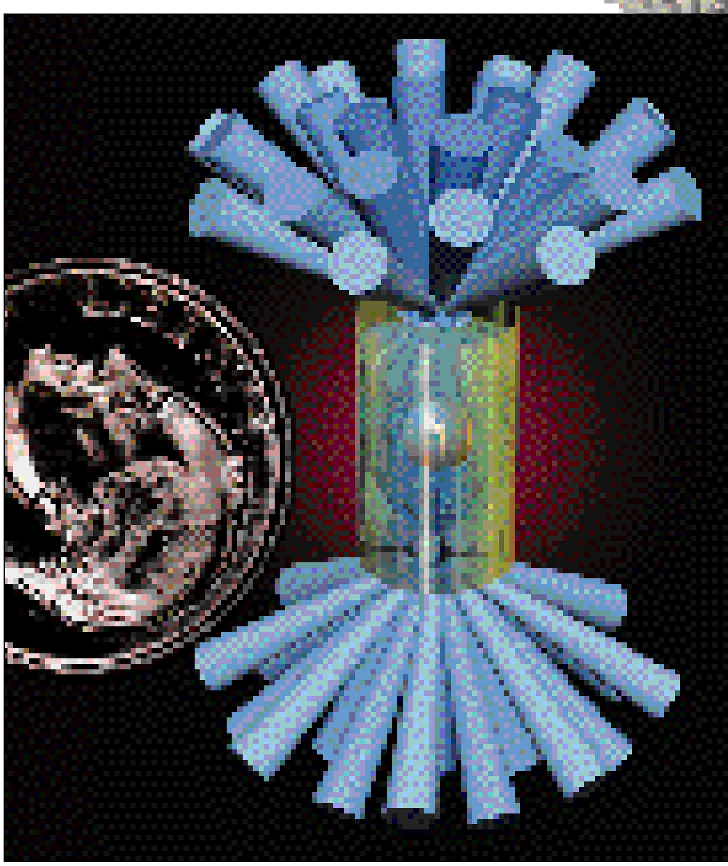


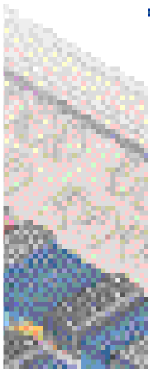


NIF

The National Ignition Facility

The Department of Energy

National Ignition Facility



For America's national security, energy, science, and economic future

On the cover:

The cover shows the overall NIF system as it will look when operation begins in 2003. The paths of the laser beams are shown in red when they are traveling through gas-filled tubes (argon or nitrogen) and in blue when they are traveling through evacuated beam tubes. The beams gain power in the lavender-colored amplifiers. As the beams enter the spherical target chamber, the final optics assemblies (shown in blue) convert the beams from infrared light to ultraviolet light and deliver enormous energy to a single target.

The back cover shows the NIF target, which will be composed of a hollow metal case the size of a dime (a "hohlraum") surrounding a spherical, BB-size capsule containing fusion fuel. When laser beams enter the open ends and strike the inside wall of the hohlraum, laser energy heats the inside of the hohlraum, creating x rays that completely surround the target. This compresses and heats the target, causing the fuel within to ignite.

NIF
The National Ignition Facility
The Department of Energy

The National Ignition Facility—
the world's largest laser supporting America's future

The National Ignition Facility (NIF) will be a U.S. Department of Energy (DOE) national center to study inertial confinement fusion and the physics of high energy and pressure. It will be a vital element of the DOE's nuclear weapons Stockpile Stewardship Program and will be used by scientists from a multitude of different institutions and disciplines to support research advancements in national security, energy, basic science, and economic development. One hundred ninety-two extremely powerful laser beams will "ignite" small fusion targets, helping liberate more energy than is required to initiate the fusion reactions. NIF experiments will allow the study of physical processes at extremely high temperatures and pressures—100,000,000˚C and 100 billion times atmospheric pressure. These conditions exist naturally only in the interior of stars and in nuclear weapon explosions.

The NIF will offer significant benefits to many different research communities throughout the world.

The NIF and national security

The NIF will play a key role in the DOE's nuclear weapons Stockpile Stewardship Program. With the end of the Cold War, America's nuclear weapons stockpile is being significantly reduced. A Comprehensive Test Ban Treaty has been signed. President Clinton and the U.S. Congress asked the DOE to establish a program that would assure the safety, reliability, and performance of the remaining stockpile in the

The NIF offers significant benefits

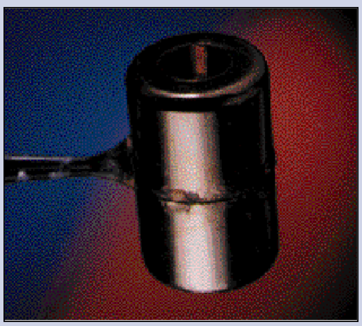
The NIF will:

- **Be a cornerstone of the Stockpile Stewardship Program, which assures the safety, reliability, and performance of the U.S. nuclear weapons stockpile under a Comprehensive Test Ban Treaty.**
- **Establish the scientific basis for electric power generation by inertial confinement fusion.**
- **Generate new basic scientific knowledge about matter under extreme conditions, advancing such fields as astrophysics.**
- **Keep the U.S. the world leader in laser and inertial confinement fusion research.**
- **Maintain and advance U.S. industry leadership in optics, lasers, and other high technologies.**
- **Create thousands of skilled engineering and industrial jobs.**

Inertial Confinement Fusion

The challenge of fusion is one of reproducing on earth the basic energy process of the sun and using it for the benefit of humanity. Our sun is a fusion energy source confined by gravity, a huge fireball heated by continuous fusion reactions. Within the laboratory, gravitational confinement is replaced by either magnetic confinement or inertial confinement of the fusion fuel.

In inertial confinement fusion, fusion fuel is contained in a small, spherical capsule about two millimeters across. This fuel capsule is compressed and heated, or "driven," by ion beams or lasers, either directly or indirectly. The NIF will use laser beams for both direct- and indirect-drive experiments.



A cylinder a few millimeters wide, with beam entrance holes on top and bottom, contains the fusion fuel capsule (see back cover).

When driven indirectly, the fuel capsule is contained in a hollow cylinder a few millimeters wide and about twice as long. The beams enter the cylinder through the ends and strike the inside of the wall, creating x rays that illuminate the fuel capsule. (When driven directly, beams strike and illuminate the capsule itself.) The fuel capsule's surface blows off like the exhaust of a rocket, causing a smooth inward push on the deuterium and tritium fuel within, i.e., an implosion. The pressure can reach 100 billion times that of the earth's atmosphere, as well as densities 20 times that of lead and temperatures of 100,000,000°C. With the high density, pressure, and temperature caused by this implosion, fuel at the center "ignites" in a fusion reaction. All of this occurs in a few billionths of a second.

The ability of inertial confinement fusion experiments to create pressures and temperatures similar to those in stars or nuclear explosions, with or without the fusion process, is valuable to scientists pursuing national defense, energy, scientific, and industrial applications.

absence of nuclear testing and preserve the core U.S. scientific and technological capabilities in nuclear weapons.

Another part of the Stockpile Stewardship Program, the Accelerated Strategic Computer Initiative, will produce the advanced computers and computer programs necessary to calculate the effects of aging and other changes on the safety, reliability, and performance of nuclear weapons. In the absence of nuclear testing, the NIF and other experimental facilities will provide the data necessary to verify the Accelerated Strategic Computer Initiative's computer programs, assess and fix problems that arise, and attract and maintain the skills of the best scientists and engineers. The NIF is unique among other facilities because it will enable the study of weapon processes at temperatures and pressures closest to those in an actual weapon test. The NIF is the only facility that will allow the direct study of fusion processes.

The NIF as a new energy resource

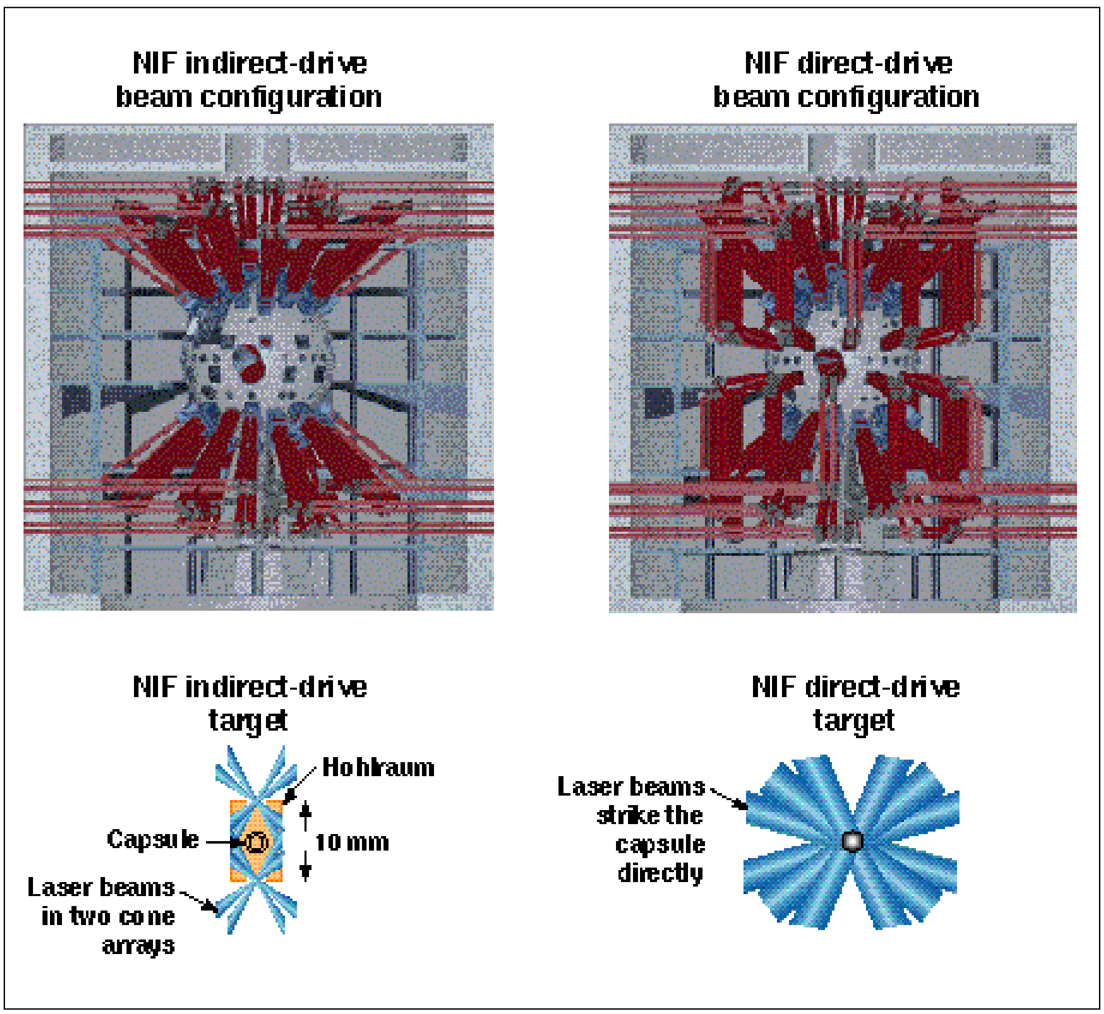
The NIF will allow America to retain its role as a world leader in the development of inertial confinement fusion as an environmentally attractive energy source. The NIF's technical goal, to achieve fusion ignition, will help establish the scientific basis for economical electrical power generation through inertial confinement fusion. Electric power generation based on fusion includes the potential for substantially more benign environmental impact than any other form of large-scale power production. For example, fusion fuel (as opposed to coal and uranium) may be "mined" from water; the radioactive waste is a thousand times less than from the fission power plants currently used, is short-lived, and is easier to dispose of; and no greenhouse gases will be produced (as with coal, oil, or natural gas).

The NIF and fundamental science

The NIF will provide many new scientific research capabilities. NIF experiments will create conditions similar to those at the center of the sun and other stars. It will be available to scientists throughout the research community, including universities, other federal laboratories, international institutions, and private industry. Because of its uniqueness, the NIF will attract the best and the brightest of scientists working in such areas as astrophysics, x-ray physics, high-energy-and-pressure plasma physics, computational physics, and advanced diagnostic techniques. The laboratories in the Inertial Confinement Fusion Program have already published extensively on these topics.

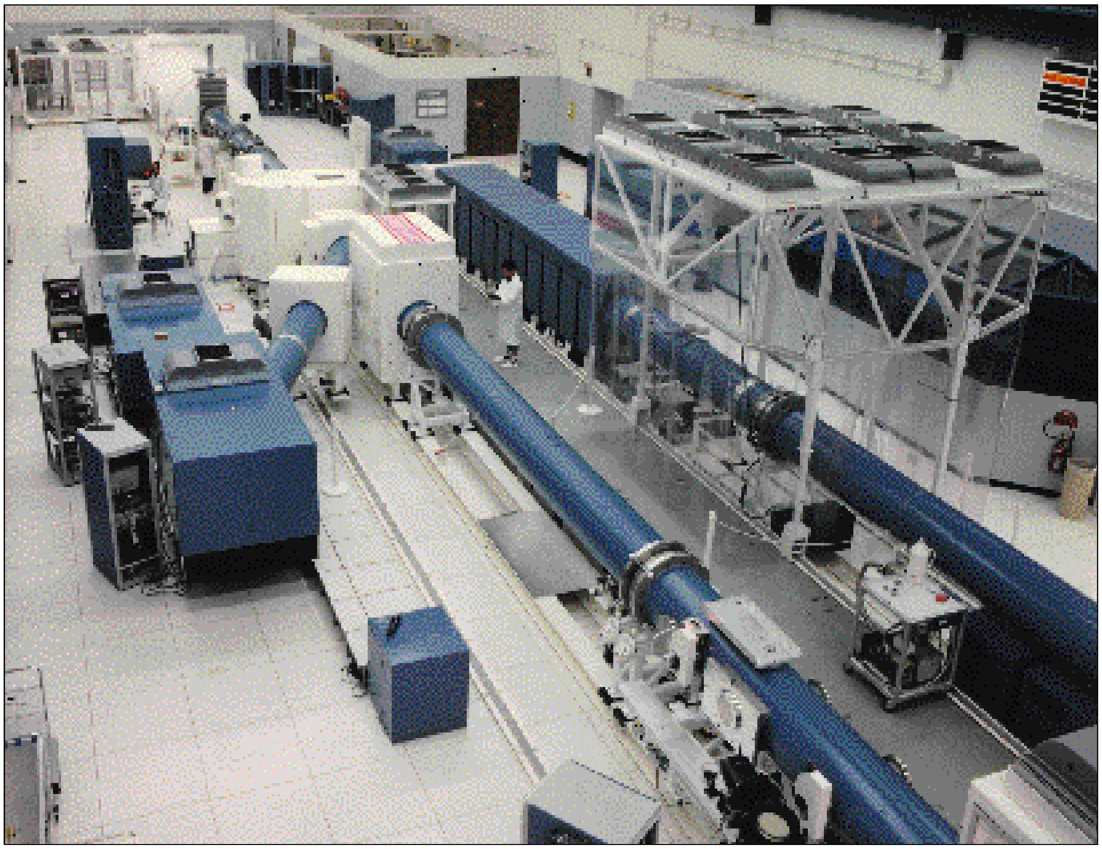
The NIF for advanced technology and economic development

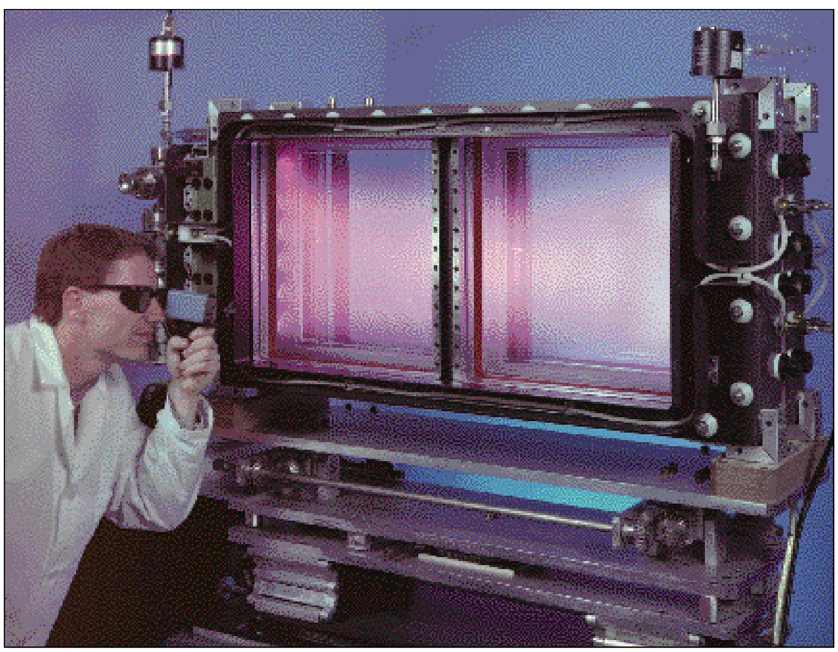
The NIF laser will play an important role in maintaining and advancing key U.S. high-technology industries, such as optics, lasers, materials, high-speed instrumentation, semiconductors, and precision manufacturing. The NIF will be the world's largest optical instrument. Industries will become more competitive in the world marketplace by providing state-of-the-art components and processes for the NIF, thus providing new and skilled jobs in America.



In the indirect-drive configuration, up to 192 laser beams enter the NIF's target chamber from top and bottom for compressing the fusion target, leaving the waist region free for diagnostic equipment. In the direct-drive configuration, some beams are moved to positions that allow symmetric spherical illumination of the fuel capsule.

The Beamlet laser, a scientific prototype of one of the NIF's 192 beamlines, has been operating at LLNL since 1994.





Very large Pockels cells switch each of the NIF's laser beams from the amplifier cavity to the transport sections of the beamlines.

The heart of the NIF: a multiple-beam laser system

The NIF will feature four main elements: a laser system and optical components, an area for the targets, an environmentally controlled building housing the laser system and target area, and an integrated computer control system.

The NIF's laser system, the heart of the facility, features 192 high-power laser beams. Together, the laser beams will produce 1.8 million joules (approximately 500 trillion watts of energy for 3 billionths of a second) of laser energy in the near-ultraviolet spectral region; this is a significant step beyond Lawrence Livermore National Laboratory's Nova laser, currently the world's largest, which produces 45 thousand joules (45 trillion watts for 1 billionth of a second). Each beam, however, is optically independent, providing outstanding flexibility in experimental design.

A full-scale prototype of one NIF beamline, called Beamlet, has been operational since 1994. It incorporates recent technology breakthroughs and material advances, such as high-damage-threshold crystals and coatings. This prototype serves as a way to validate the proposed laser architecture, to demonstrate full NIF performance, and to test operational procedures.

The light from the NIF's beams will be tightly focused onto a tiny target located inside a 10-meter-diameter spherical chamber equipped with the most advanced diagnostic equipment. The target will be filled with cryogenic fusion fuel. The laser light will compress (to pressures greater than 100 billion times that of earth's atmosphere) and heat the fuel to produce fusion reactions yielding up to 10 times the laser energy delivered to the target.

This sequence of events will produce a miniature star. Although this miniature star will exist less than a billionth of a second, that is long enough to make accurate measurements of states of matter at high temperatures and pressure.

Making the NIF happen

The NIF's total project cost is $1.2 billion. Engineering design began in 1996, construction started in 1997, system start-up of one bundle of eight beams is planned for late 2001, and all 192 beamlines will be available at the end of 2003. Once built, the NIF will operate for more than 15 years, with annual operating and maintenance costs of approximately $60 million. The NIF will be located at Lawrence Livermore National Laboratory (LLNL), and is being designed, built, and operated as a national facility through a partnership of LLNL, Los Alamos National Laboratory, Sandia National Laboratories, and the University of Rochester's Laboratory for Laser Energetics. General Atomics is a partner in development of NIF target technology.

An ignition facility was strongly recommended by the National Academy of Sciences and the DOE Fusion Policy Advisory Committee in their 1990 reports. More recently, the NIF was endorsed by the DOE Inertial Confinement Fusion Advisory Committee and the JASON Review Committee, a leading academic-based Department of Defense scientific advisory panel.

The NIF's timeline

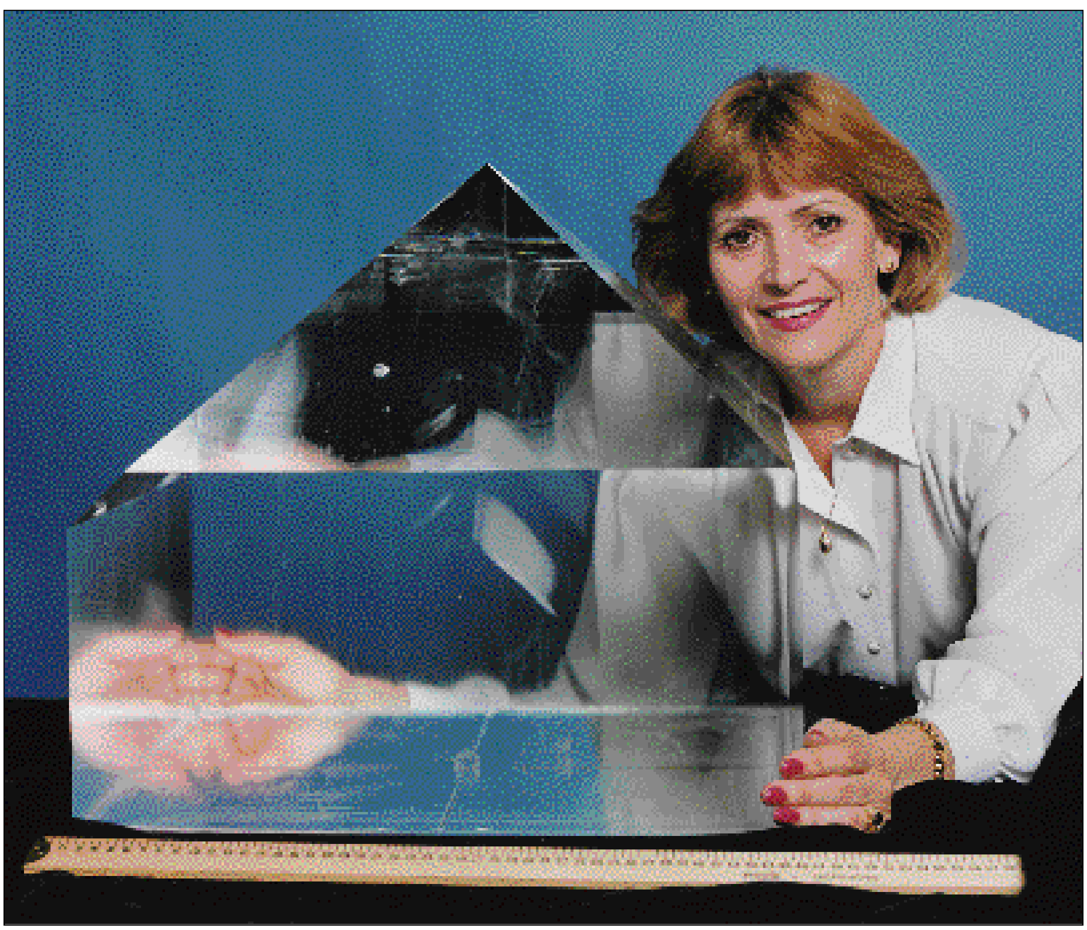
The DOE's procedure for making the NIF a reality is based upon numbered "critical decisions" (CDs) made by the Secretary of Energy that led to their Record of Decision (ROD) to build the NIF. Below is the sequence of events as it occurred and the schedule for concluding the project.

January 1993	**CD1—affirmed the need for the NIF and authorized a conceptual design study.**
October 1994	**CD2—approved the formal start of the project.**
December 1996	**ROD—completed the *Programmatic Environmental Impact Statement* and the National Environmental Policy Act process and named LLNL as the site for the NIF. Line-item funding was also approved by Congress in the FY 1996 budget.**
March 1997	**CD3—approved the start of construction and procurement processes.**
End of FY 2001	**Initial operation capability planned with one bundle of eight beamlines.**
End of FY 2003	**CD4—scheduled end of project.**

A Project Specific Analysis satisfying National Environmental Policy Act requirements was prepared as part of the *Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*. The NIF will meet all applicable environmental, safety and health, and quality assurance orders and regulations and has been identified as a low-hazard, radiological facility based on the *Preliminary Hazards Analysis* report. Minuscule quantities (less than 1/10,000 of an ounce) of tritium are associated with the NIF; the facility's operations will cause insignificant impact to the public.

Industry and inertial fusion: long-term partners

Industry has long been a major participant in the rapid progress of inertial confinement fusion research. That partnership is continuing for the NIF; about three-quarters of the $1.2 billion cost of the NIF will be placed in industrial contracts. For example, as in previous inertial confinement fusion laser facilities, the NIF requires advances in the precision optics industry. The NIF will require 8,000 large-diameter (more than 1 square foot) optical components and more than 15,000 smaller ones. It will contain 40 times more polished precision optical surfaces than the Keck telescope (the world's largest) in Hawaii. Companies including Corning, Eastman Kodak, Hoya, Schott Glass, Spectra Physics, Tinsley Laboratories, WYKO, Zygo, and many others are helping develop new optical components, instruments, and mass-production manufacturing processes to ensure that the NIF's optics can be produced within performance, cost, and schedule requirements. Ralph Parsons,

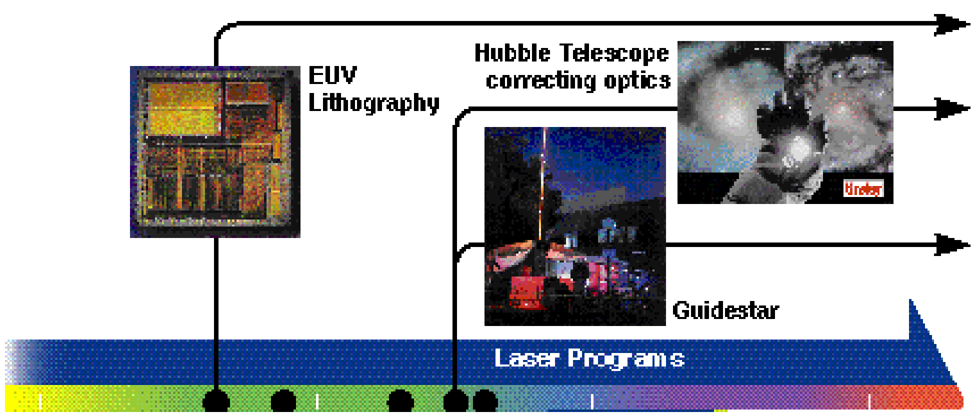


Rapid growth methods have been developed for the potassium dihydrogen phosphate crystals that are required to convert the infrared NIF beams into the ultraviolet spectral region.

Inc. and A.C. Martin are designing the main NIF building and the optics assembly building. Sverdrup Facilities is the construction manager. TRW, SAIC, Physics International, and Northrup / Grumman are assisting with the design of special equipment. It is expected that more than 200 companies from construction and manufacturing industries will participate in the project.

The laboratories and companies participating in the NIF project are located throughout the United States. As part of the *Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*, Argonne National Laboratory estimated that the NIF construction project would generate more than 6,000 jobs nationwide, almost 3,000 of those in the San Francisco Bay Area near LLNL. These jobs have a higher than average value added to the economy because many are in the high-technology manufacturing areas.

Of greater importance than the jobs created, however, is the long-term benefit of the technology transfer to industry that will result either from participation in the construction project itself or from using the technologies developed for the NIF or within the Inertial Confinement Fusion Program for spin-off applications. This is illustrated in a 1997 independent study by Bay Area Economics, a consulting firm in Berkeley, California, guided by an academic committee from U.C. Berkeley's Institute of Urban and Regional Development and the Berkeley Roundtable on the International Economy. That study identified technologies, such as precision optics manufacturing and high-speed instrumentation, that would be positively impacted by the requirements for the NIF. It also identified some potential near-term commercial products, such as medical lasers, flat-panel displays, and micro and large optical components for

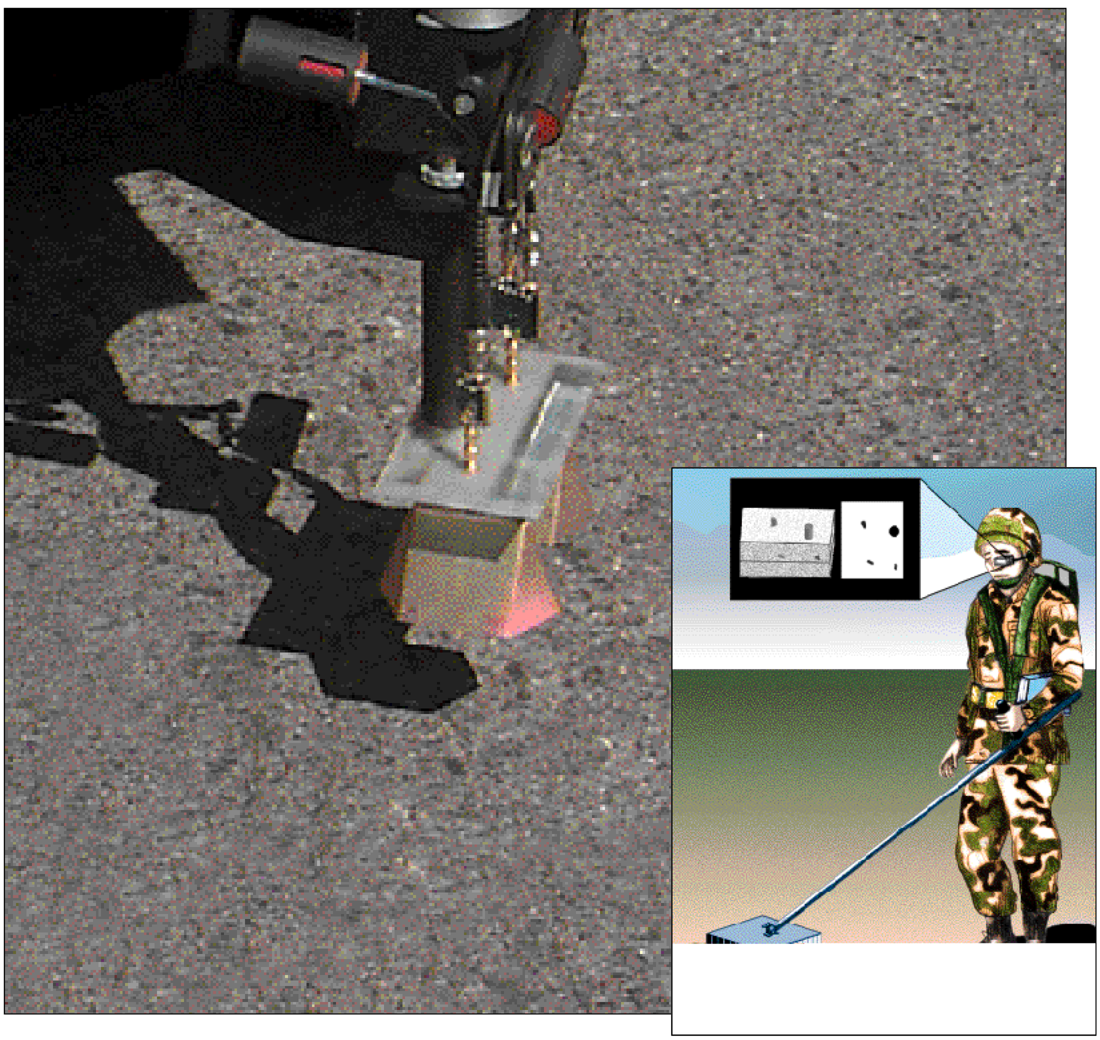


Many industrial spin-offs result from America's inertial fusion effort. Technologies developed for the Inertial Confinement Fusion Program have found near-term applications in many areas: for example, extreme ultraviolet lithography for making better computer chips and micropower impulse radar for a multitude of uses, from fluid level sensors to finding live victims trapped under disaster rubble.

defense and commercial systems, that are likely to benefit from NIF spin-off technologies.

The study examined in considerable detail extreme ultraviolet lithography and micropower impulse radar, both based on technologies developed in the Inertial Confinement Fusion Program. Extreme ultraviolet lithography, a process that allows more circuits to fit on a microchip, could have a dramatic impact on the $160 billion-per-year computer chip manufacturing industry. Micropower impulse radar is a low-cost electronic circuit that has many applications, such as collision avoidance radar for automobiles, fluid level sensors, detectors for finding plastic mines for safe removal, and search devices for locating live earthquake or bombing victims under rubble. This invention has been licensed by more than 20 companies.

The scientists and engineers of the Inertial Confinement Fusion Program are recognized internationally for their innovation of both near- and long-term applications and have won many awards. For example, LLNL staff alone received 30 prestigious R&D 100 Awards through 1996. New changes in federal law now make it possible to get these inventions into commercial applications much more quickly. The overall conclusion of the Bay Area Economics study was that the NIF and inertial confinement fusion "will push the state of the art in several technology areas that are likely to have significant impacts on the economy over the next 10 to 15 years."



This antenna element (above right) on the High Speed Electromagnetic Roadway Mapping and Evaluation System (HERMES) robotic cart analyzes road defects. It uses electronics technology based upon the micropower impulse radar (MIR), which spun off from the Inertial Confinement Fusion Program. MIR and 3D imaging technology are also being used to detect plastic land mines (far right).

The NIF partnership represents much of America

The NIF partnership includes representatives from throughout government, industry, and the academic sector. The Department of Energy, through Defense Programs, has overall authority for the project, composed of an integrated national contractor team.

The major research participants are:

Lawrence Livermore National Laboratory — project integration; site and conventional facilities design; laser, target physics, and diagnostics; integrated computer control systems; and optical components.

Los Alamos National Laboratory — technical risk assessment; laser / target diagnostics; and target physics.

Sandia National Laboratories — power conditioning system; target chamber and diagnostics.

University of Rochester — direct-drive option.

General Atomics — target fabrication technologies.

These five institutions have successfully cooperated for more than a decade on laser fusion experiments, as well as planning for the NIF. In the same spirit of teamwork, the NIF research team will include contributions from hundreds of other scientists nationwide.

As with the building of Nova and other inertial fusion facilities, building the NIF will require the best of America's construction industries. Furthermore, the NIF's technical successes will depend upon the most advanced products and processes offered by hundreds of high-technology companies from throughout the United States.

Visit the NIF on LLNL's Web page at
http://lasers.llnl.gov
and on DOE's Inertial Fusion Web page at
http://www3.dp.doe.gov/ifnif/icf.htm

For More Information

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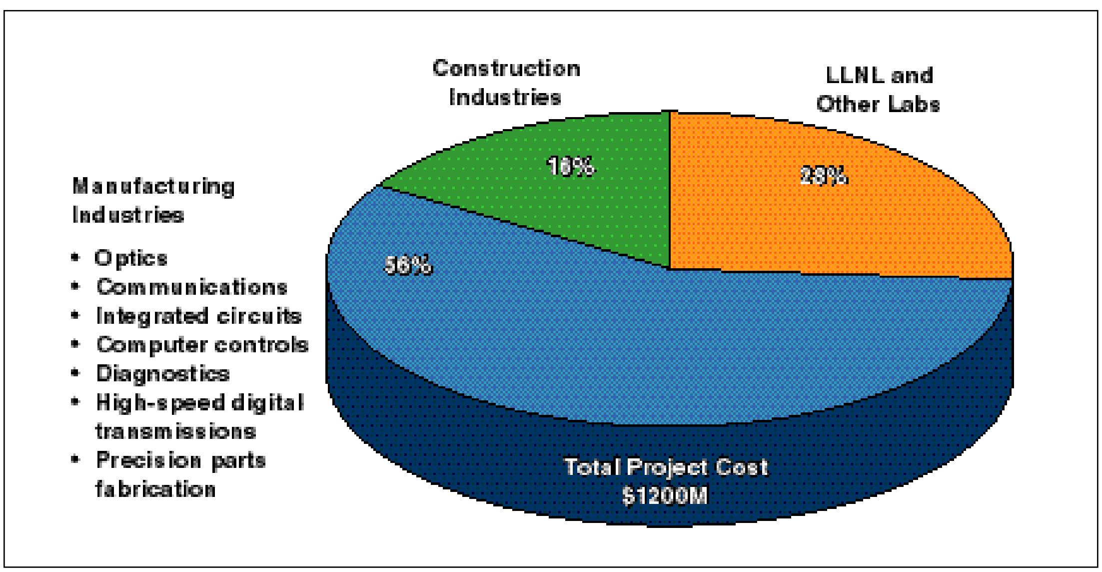

Argonne National Laboratory has estimated that, at its peak, the NIF Project will create more than 6000 jobs nationwide.